

ABSTRACT

In one aspect the invention provides a method for laser induced breakdown of a material with a pulsed laser beam where the material is characterized by a relationship of fluence breakdown threshold (F_{th}) versus laser beam pulse width (T) that exhibits an abrupt, rapid, and distinct change or at least a clearly detectable and distinct change in slope at a predetermined laser pulse width value. The method comprises generating a beam of laser pulses in which each pulse has a pulse width equal to or less than the predetermined laser pulse width value. The beam is focused to a point at or beneath the surface of a material where laser induced breakdown is desired.

The beam may be used in combination with a mask in the beam path. The beam or mask may be moved in the x, y, and Z directions to produce desired features. The technique can produce features smaller than the spot size and Rayleigh range due to enhanced damage threshold accuracy in the short pulse regime.

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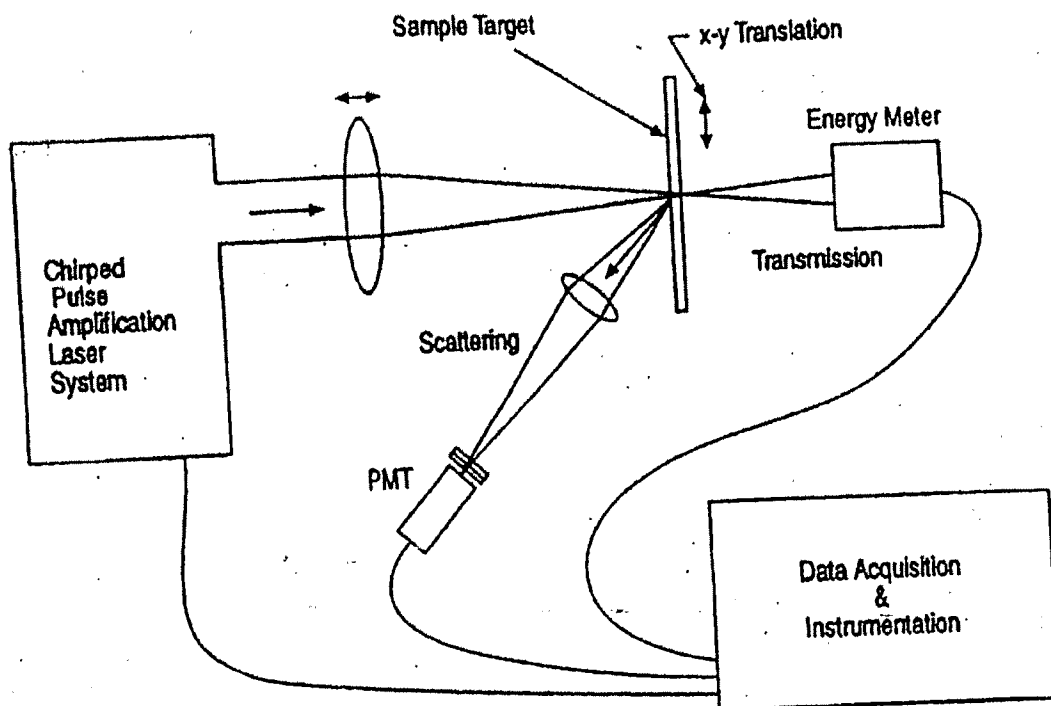


FIG. 1

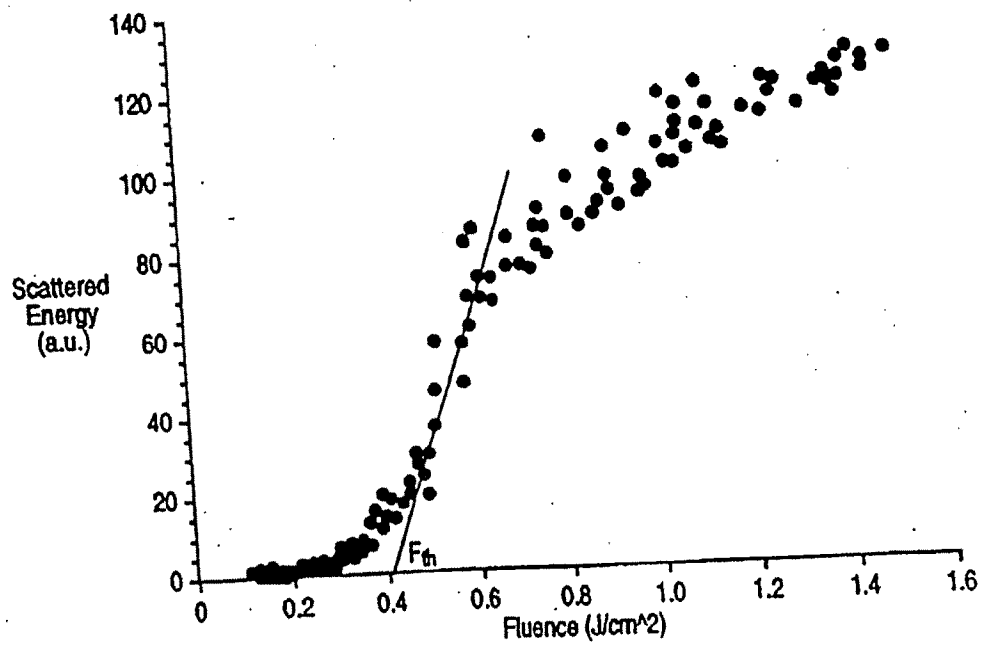


FIG. 2

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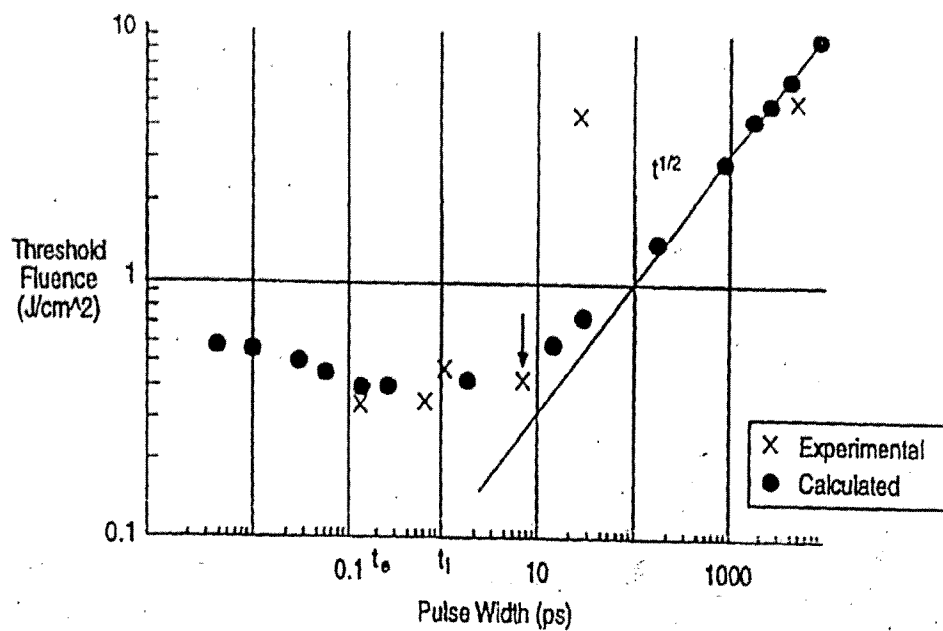


FIG. 3

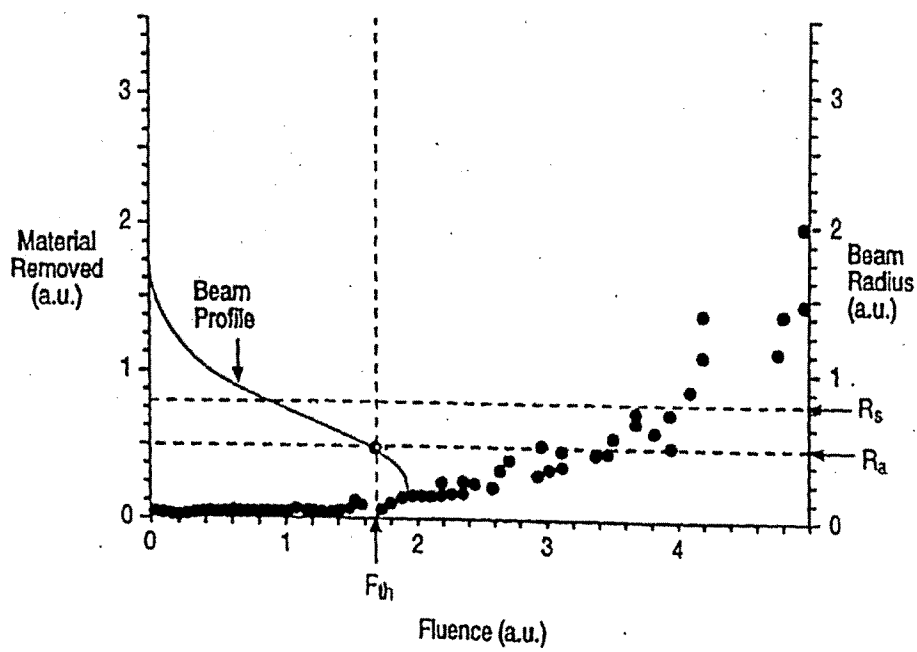


FIG. 4

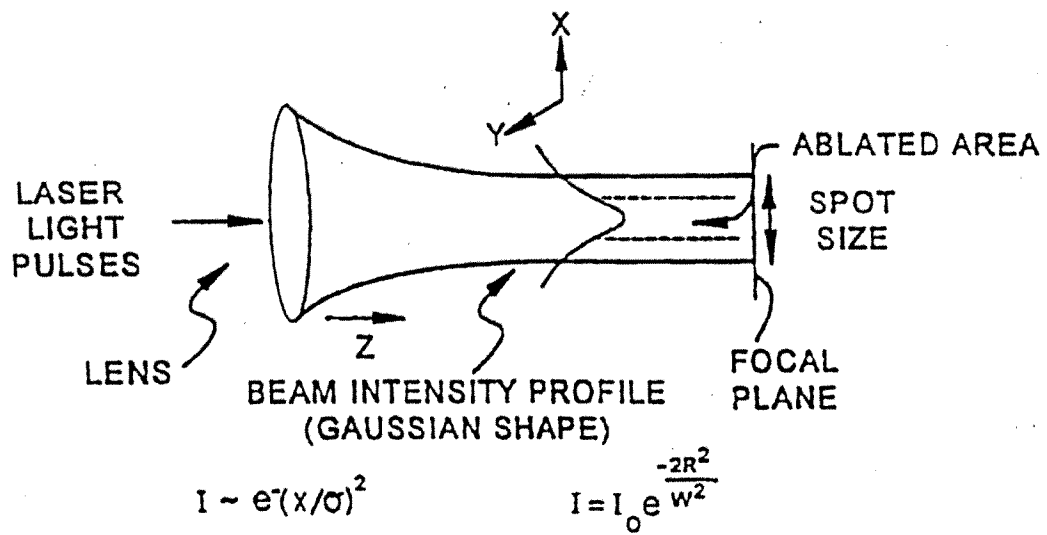
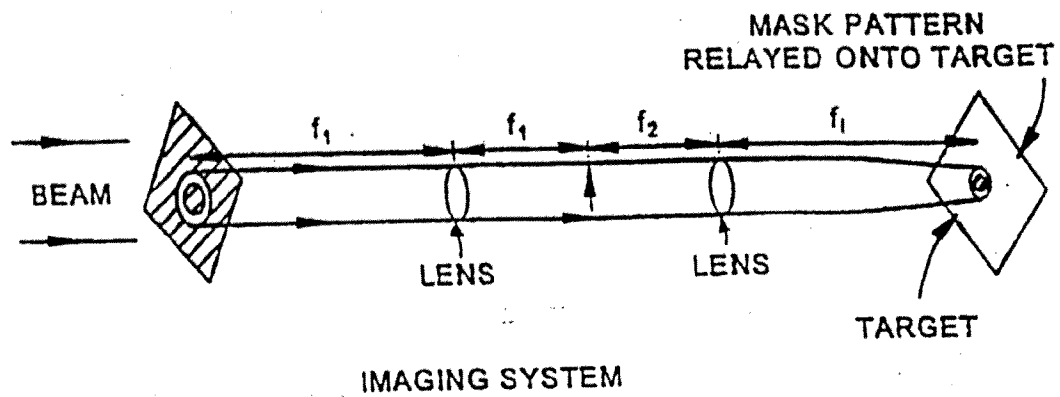


FIG.5

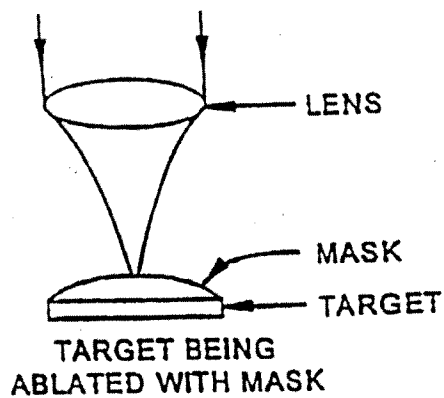
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f_1, f_2 - FOCAL LENGTH OF LENSES
 $f_1 = mf_2$ WHERE m IS ARBITRARY



MASK - CROSS HATCHED AREAS
ARE OPAQUE TO LASER WAVELENGTH

FIG.6A



TARGET AFTER ABLATION IS ESSENTIALLY
IMAGE OF MASK.

TARGET AFTER ABLATION

FIG.6B

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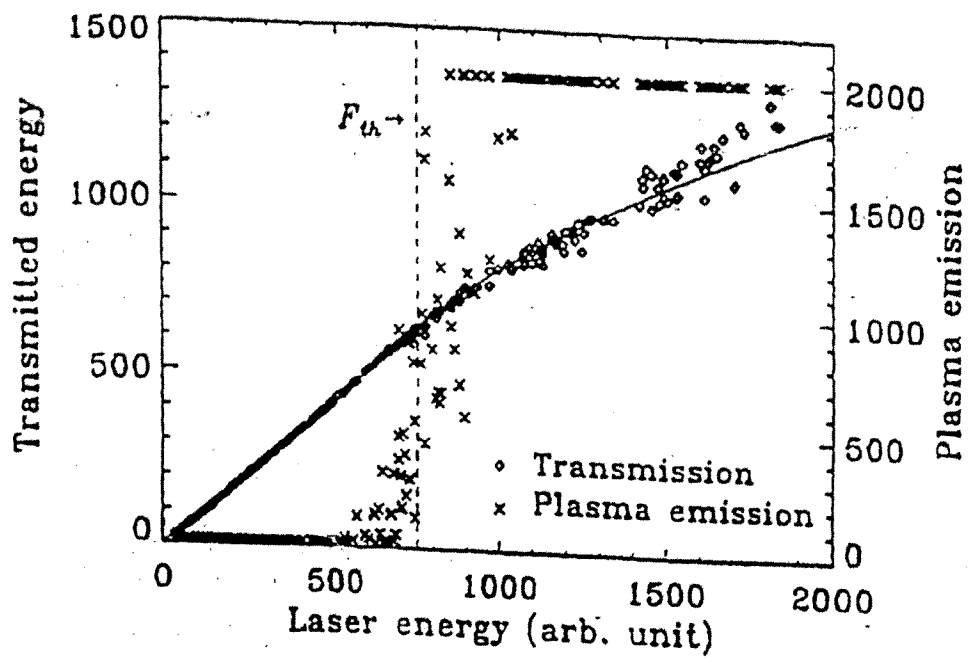


FIGURE 7

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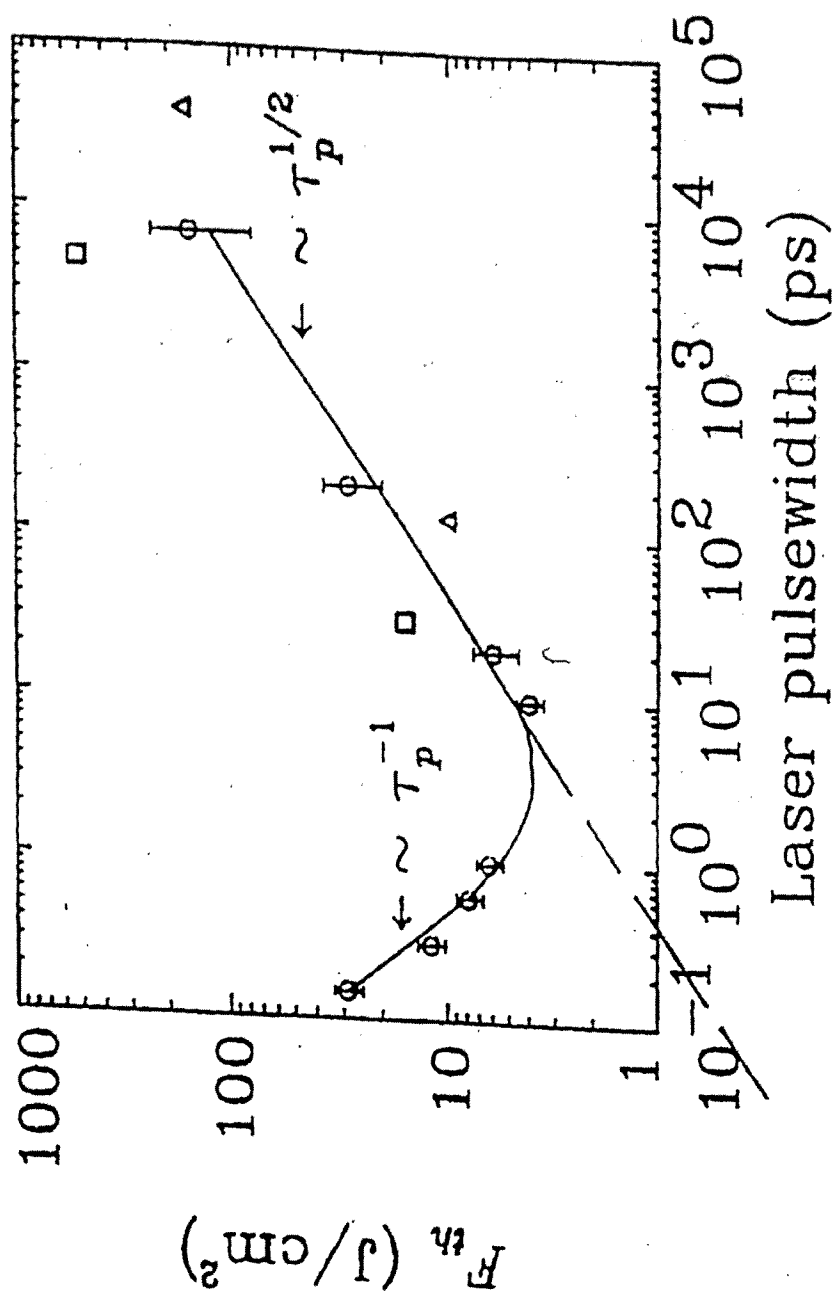


FIGURE 8

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DAMAGE THRESHOLD FOR CORNEA

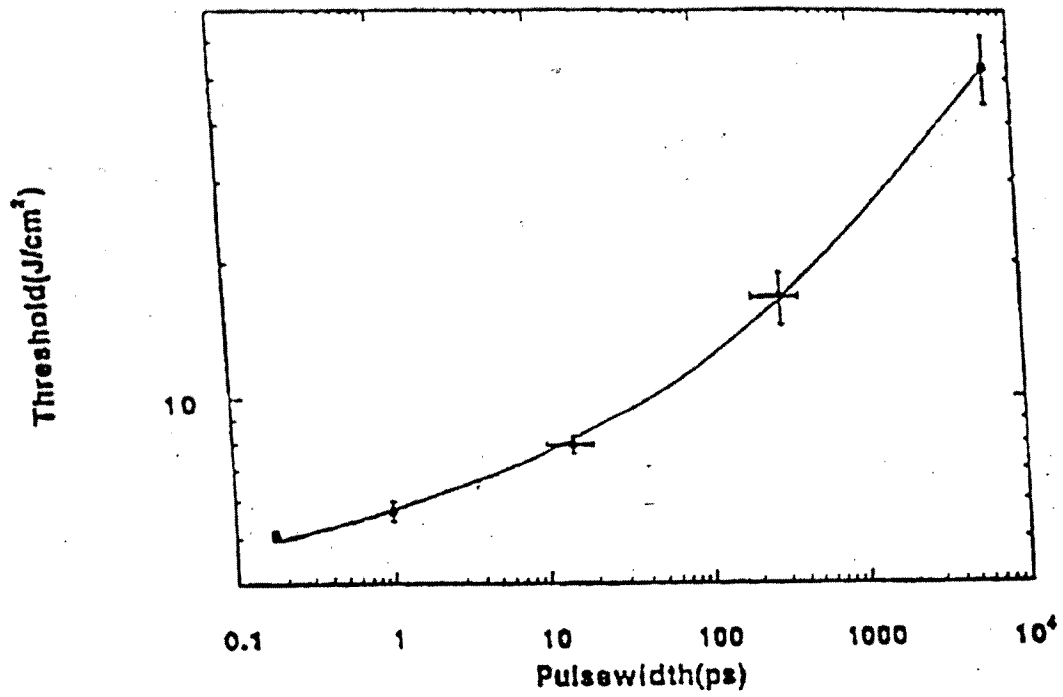


FIGURE 9

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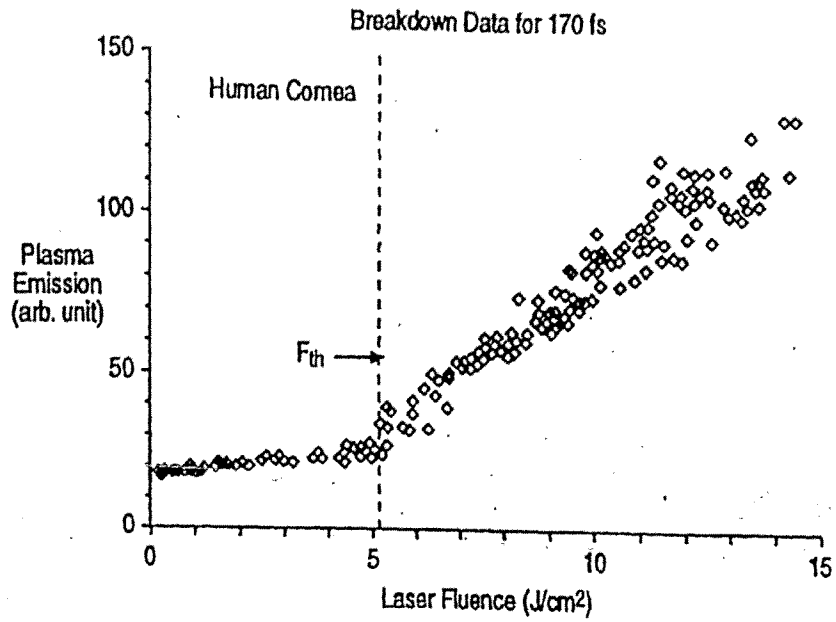


FIG. 10

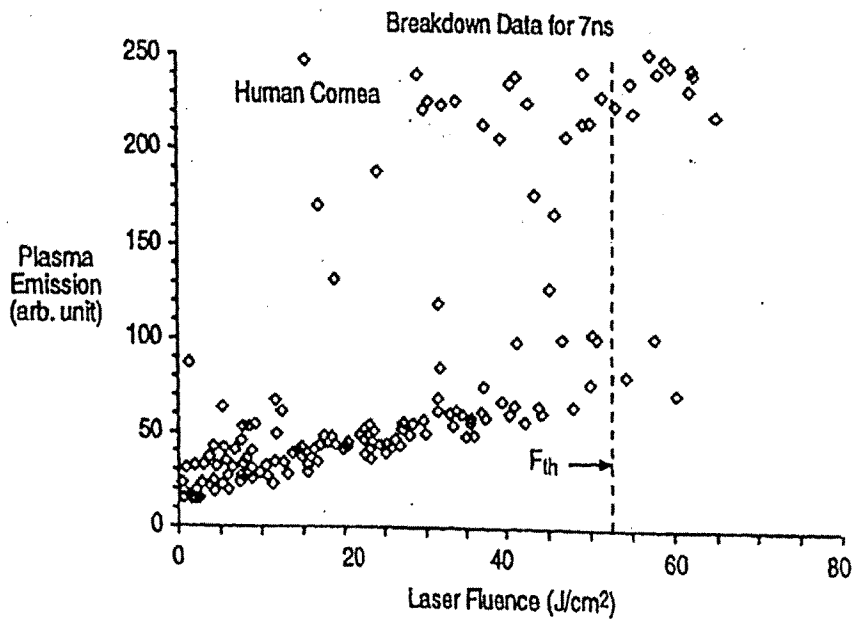


FIG. 11

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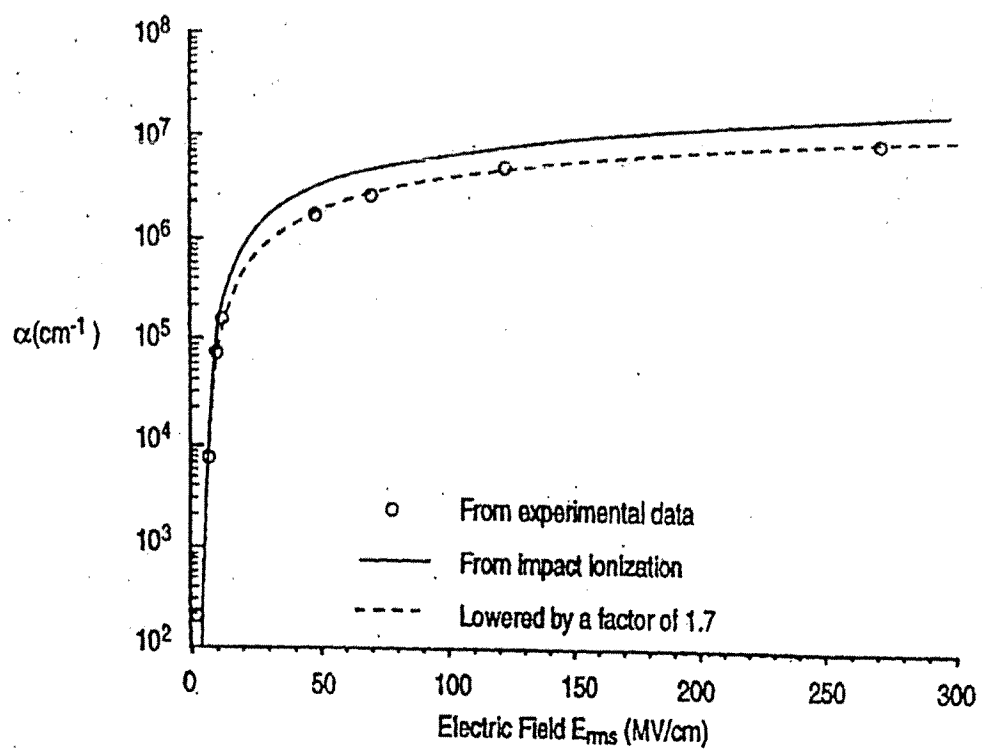


FIG.12

The diagram illustrates the focusing of a laser beam. A vertical double-headed arrow on the left indicates the beam's direction. The beam is represented by two converging lines that meet at a focal point. A horizontal line marks the focal plane, labeled "RAYLEIGH RANGE" with a vertical double-headed arrow and the symbol z_r . Below the focal plane, the beam is shown as a dashed line. A vertical line represents the target, with four dots indicating the beam's position at different depths. Two horizontal lines, labeled "d" with a vertical double-headed arrow, represent the beam's diameter at two different depths. Arrows point from the text "DAMAGED SPOT" to the two dots on the target line that are between the two diameter lines.

FIG. 13B